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EDL-M473

DA 36-039 SC-87499

Reliability of Welded Electronic Connections

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Government Systems Management
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PREPARED FOR THE U.S. ARMY SIGNAL CORPS

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ELECTRONIC DEFENSE LABORATORIES

P. O. Box 205

Mountain View, California

Addendum No. 1 to Technical Memorandum EDL-M473

RELIABILITY OF WELDED ELECTRONIC CONNECTIONS

1. Additional information for Figure 6: There were 348 clean welds and 348 salted welds per curve.

2. Modification for Figure 8: In the lower schmoo diagram, the Kovar was welded with Molly electrodes. The nickel was welded with RWMA #2 electrodes.

3. Modification for Figures 7, 10 and 14: The scale markings in the lower right hand corners are meant to denote 1/400 of an inch.

4. Modification for Figure 13: The marking drawn as □—•— denotes 112 clean welds rather than 224.

5. Test results subsequent to the above report: As of 1 July 1962, no failures have occurred; 10 million weld hours have accumulated.

ELECTRONIC DEFENSE LABORATORIES
P. O. Box 205
Mountain View, California

TECHNICAL MEMORANDUM
No. EDL-M473
23 May 1962

RELIABILITY OF WELDED ELECTRONIC CONNECTIONS

Mark Hurowitz

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SYLVANIA ELECTRIC PRODUCTS INC.

RELIABILITY OF WELDED ELECTRONIC CONNECTIONS

Mark Hurowitz

Among the many reports on the reliability of welded electronic equipment, there are few investigations of the welded connections themselves. Instead, the available data is primarily on encapsulated modules and assemblies, and presents only scant description of the variables involved. But as early as 1951, experience with welded connections revealed potential problems and implied a need for investigation. It is in view of this need that the tests discussed here are being conducted.

This paper is essentially concerned with the most fundamental of three potential processing areas capable of introducing unreliability in any module. Rather than premature failure of components due to thermal and mechanical stress during assembly, or mechanical and thermal damage from encapsulation, the basic consideration here is reliability in joints themselves. More specifically, it is reliability in welded joints utilized for electrical connections between components for space technology and high strength electronic assemblies (Figure 1). Until we know how good such a joint is, how much strength is in its basic assembly, it is impossible to specify fundamental finishing treatments and appreciate potential applications.

With the problem thus narrowed, its analysis takes the form of several questions. The EDL tests were designed to answer the following: (1) What is the effect of current flow on a joint? Does it induce galvanic action or corrosion in the capillaries left by welding? (Figure 2 shows typical microphotographs of soldered and welded joints. Note the capillary space in the weld, left for accumulating moisture that possibly could bring about eventual destruction.) (2) What is the effect of salt contamination on the material being welded? How clean must the leads be before welding? (3) When different metals are joined, is there any tendency toward corrosion? (4) Are there any adverse effects when operating in a high relative humidity? Clearly, these questions must be answered if we are to define a good weld and control the welding process for high electrical reliability.

The importance of such aims is evident. Welds have been used for a long time, and are with us whenever we build a piece of electronic equipment. But when they are used in vacuum tubes, transistors, diodes, relays, capacitors and so on, it is under protected conditions. Since the present series of tests is for the purpose of determining how welds hold up under the worst case conditions, the joints being tested are in the open, unprotected by films, encapsulants or surface coats, and have continuous current running through them. Excepting those running in high humidity, their environment has not been controlled. Figure 3 shows the weld life test bench.

In the testing itself, measurements for joint resistivity and joint strength are made on each of several sets of samples. The sets are arranged in "ladders" (Figure 4) composed of 58 joints in series prepared by welding a nickel strap across on each side of a Mylar support and then cutting out alternate sides with special cutters. The number of joints is maximized, with as little metal between welds as possible.

Pull test samples are run in series with resistance samples. Joint resistance is measured with a General Radio Impedance Model 650-A bridge, with allowance made for the test lead resistance. Pull strength is measured on a Hunter spring gauge. In this latter test, a combination shear, peel and tensile strength is measured. The pull tests are performed so as to exaggerate the joint failure mechanisms rather than to allow a failure in simple shear tension or torsion. The sample is constrained in only one degree of freedom, which yields the worst case encountered in module failure. As the schmoo diagram in Figure 5 indicates, joint strength inside the acceptable area remains fairly uniform.

At present, there are four tests in progress, with the longest running over 6000 hours. The first series was made with nickel ribbon welded to #24 buss wire. Approximately 696 joints were involved in the experiment, half of them welded after cleaning in isopropal alcohol and the other half after immersion in a sodium chloride solution (5. 5 gr. salt to 500 ML H_2O). Prior to welding, the leads (and interconnecting buss) were air-dried. Then, assuming that any polarization effects would show up in polarity reversal of the alternate joints, DC current was passed through the test samples.

Since the pull test samples have not been isolated to reflect the direction of current flow, polarization effect must be inferred from the change in spread of the pull test data. Figure 5 , a schmoo diagram for this weld combination, illustrates the selected welding point. The initial current of . 2 amps through the specimen was increased to 3 amps after 1, 650 hours to further accelerate the tests. As Figure 6 indicates, the results of the tests are that joint resistance decreased while a slight drop in joint strength also

occured. Since no gross increase in scatter with time is evident, there are few, if any polarization effects. No joint degradation is apparent in the before and after microphotographs in Figure 7 .

Test 2 involves nickel strap to Kovar transistor welds. The effect of heat balance on the welds was in question. Two sets of samples were welded at identical settings, with the exception that the electrodes were reversed. The heat balance is reflected in the schmoo diagram in Figure 8 , where the relative difference in allowable welding area is illustrated. Figure 9 shows the results of the tests. Although the total joint resistance for both sets of data is indistinguishable, there has been a drop in strength in the samples welded with the Molly in contact with the Kovar. For further clarification, microphotographs taken before and after the tests are presented in Figure 10.

Tests 3 and 4 involve nickel ribbon to 1/4 watt resistor leads (RC07GF 220K). Test 3 is essentially the control for Test 4, and is used to evaluate the effects of humidity. In Test 4, two sets of leads are running under 95% relative humidity, with one set salted and the other clean. Figure 11 shows a comparison between the sets of leads after 3,700 hours. An isostrength diagram for the weld is shown in Figure 12. Figure 13 represents the life test data of resistance and pull strength. Notice that there is little difference with regard to the salted leads. See Figure 14 for the before and after microphotographs.

A total of 2,080 joints are now being tested in the resistance series, with additional ones available for pull test samples. In all tests, 6.9×10^6 weld hours are represented under conditions "conducive" to joint failure. To date, however, these conditions have not produced joint failure. All resistance samples have not only behaved reasonably, but have actually shown a slight tendency to improve. In the meantime, joint strengths have suffered only a slight deterioration.

The conclusions to be drawn from this series of tests are the following: (1) Salt contamination and/or high humidity have no appreciable effect on the joint strength or resistance of welded joints. However, microphotographs of the high-humidity salted samples have revealed extensive deterioration and corrosion in the base material. Component lead cleaning in solvent prior to use is sufficient, and subsequent handling with reasonable cleanliness will not effect weld life reliability. (2) Properly welded joints are reliable without protection from moisture. they should not suffer appreciable deterioration in the time scale and under the conditions encountered in these tests, provided they have been cleaned. Regarding subsequent finishing operations, these cannot yet be justified on the basis of joint deterioration. They may, however, be required for protection against people, the hardest environment of all to design against.

As indicated in published data, subsequent treatments can maintain reliability levels. But the designer may exercise a high degree of freedom. He may, for example, provide support with methods similar to those used in the tube industry (i. e. , methods which do not employ hermetic sealing or encapsulation, thereby affording both the joints and the components protection from the shrinkage forces inherent in the encapsulating materials). At EDL we are conducting vibration and shock tests on "nude" modules in an effort to determine their failure points. As of now, however, and with the tests continuing, it is too early to offer a report.

Lately, the question is often asked: Why bother to weld? There are many reasons, of course: the low thermal shock to components, the high degree of control possible, the high mechanical strength and so on. But the most basic reason is the plain fact that some joints cannot be made with solder. For example, consider the extremely small binary counter stage shown in Figure 15. Its overall dimension is .2" x .4" x 1", including some 19 components and a replaceable light bulb. When attempts were made to solder such bulbs in place, the solder bridged across the bulbs and shorted them out. Hence, it was appropriate to weld them. The typical spacing between weld centers here is 0.040 inches.

As components become smaller and space requirements increase, it is obvious that some form of welding must be used to preserve and complement the advances in the component state-of-the-art.

This work has been performed under the auspices of the U. S. Army Signal Corps Contract DA 36-039 SC-87499.

ACKNOWLEDGMENT

The author wishes to acknowledge ANAMET Laboratories, Inc., of Berkeley, California, for preparation of the microphotographs used in this paper.

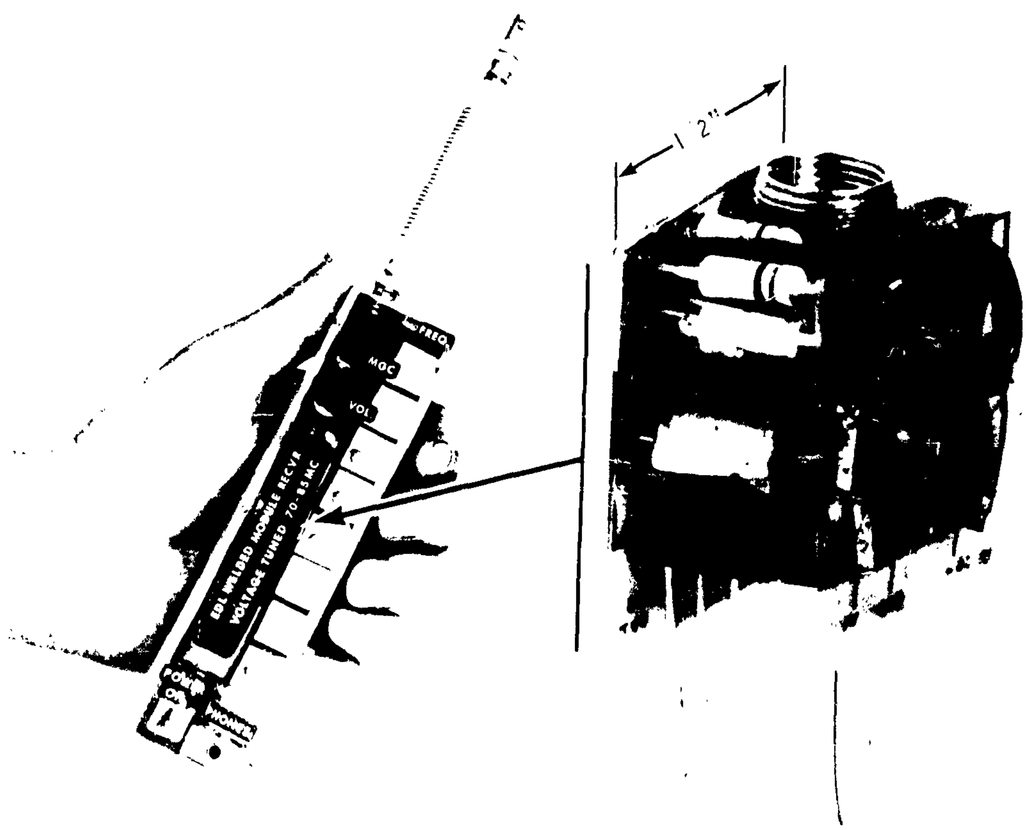
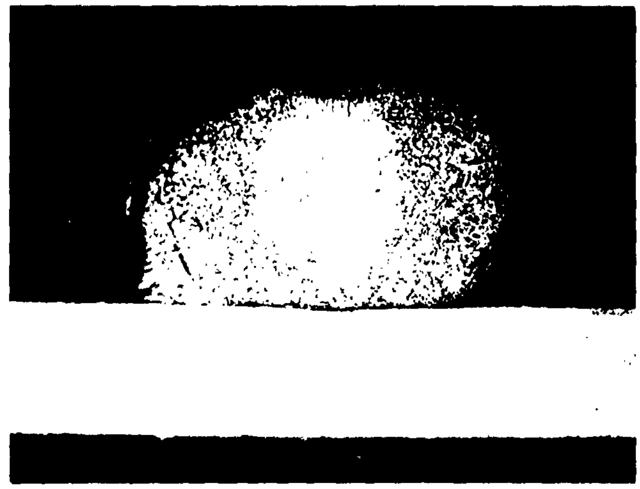
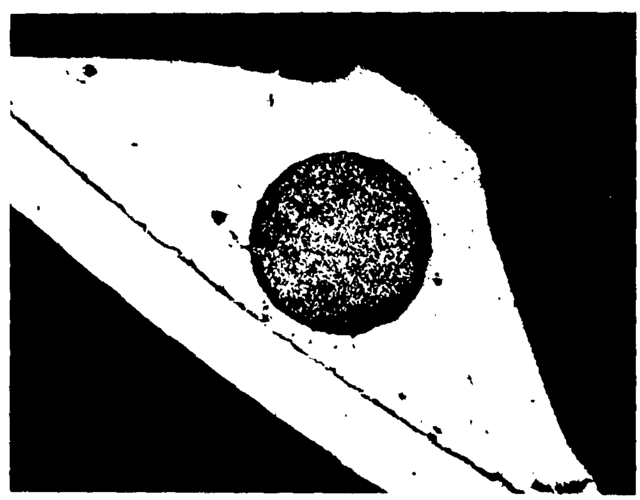


Figure 1

Miniature Receiver with Typical Welded Module



TYPICAL WELDED JOINT



TYPICAL SOLDERED JOINT

Figure 2

Comparison between Welded and Soldered Joints

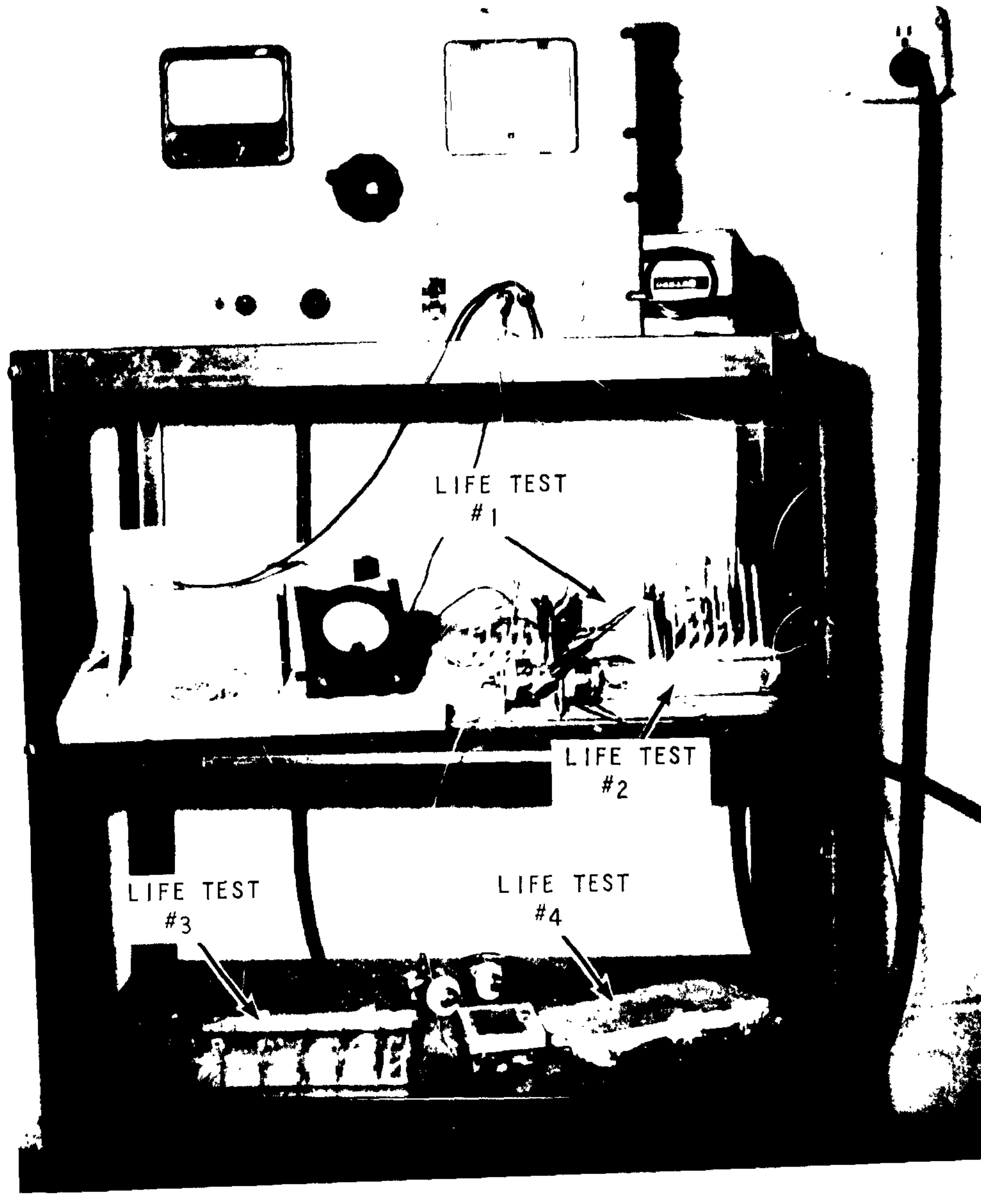


Figure 3

Life Test Bench

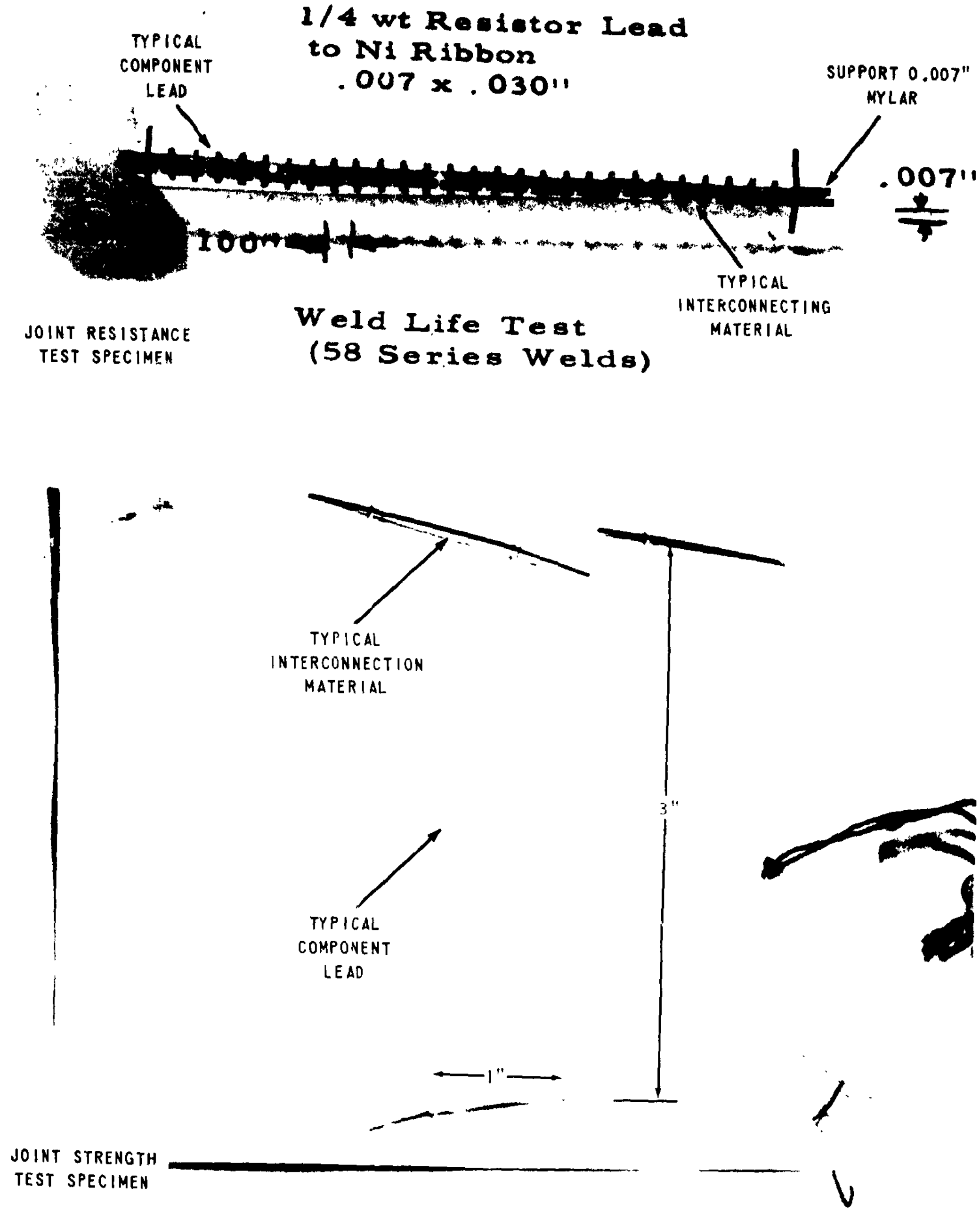


Figure 4

Typical Test Specimens

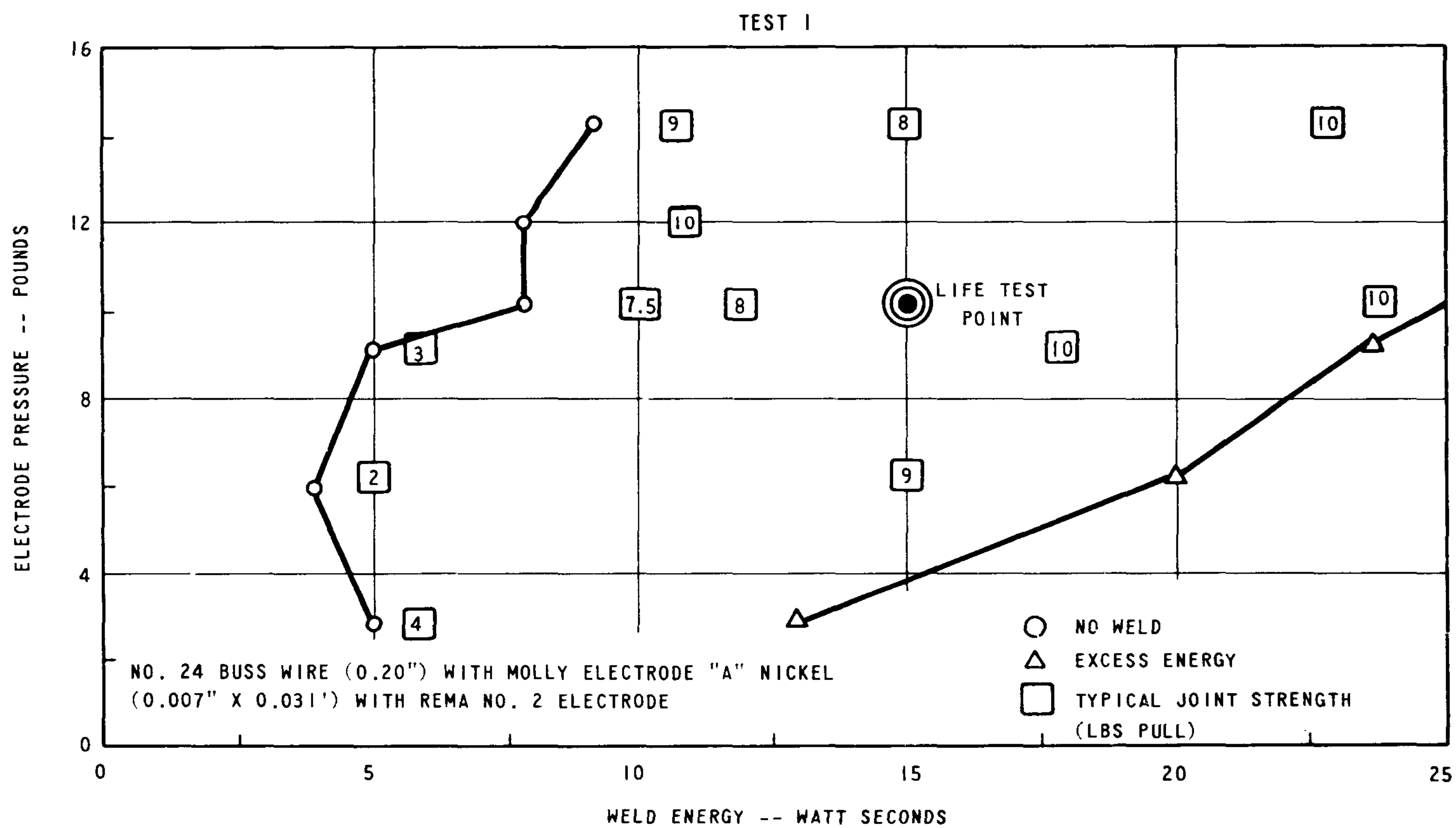


Figure 5

Test No. 1 -- Schmoo Diagram Tinned Buss Wire to Nickel Welds

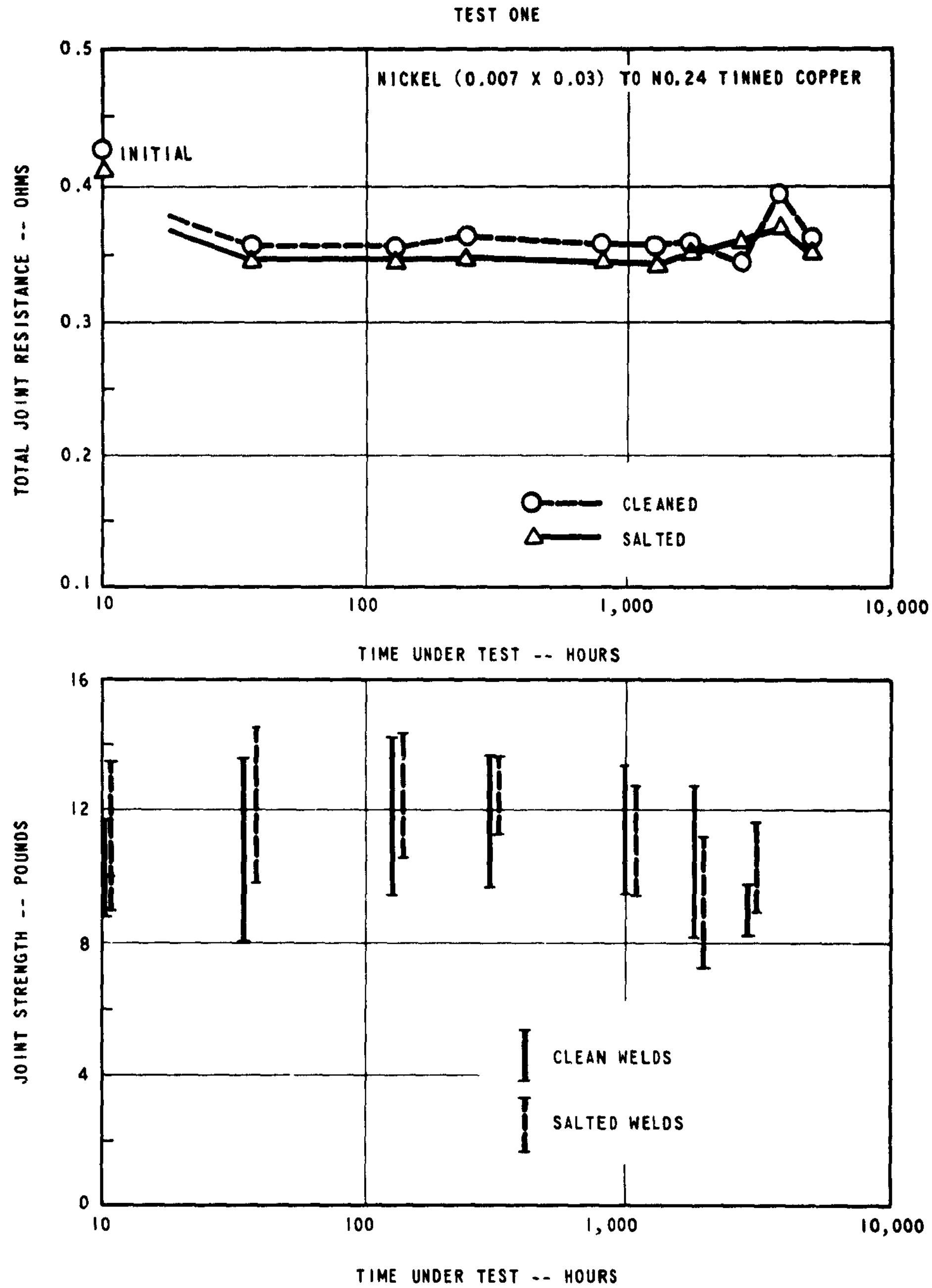


Figure 6

Test No. 1 -- Joint Resistivity and Joint Strength of Tinned Copper to Nickel Welds Life Test Current 0.3 amperes to 1950 hours, 3.0 amperes thereafter.

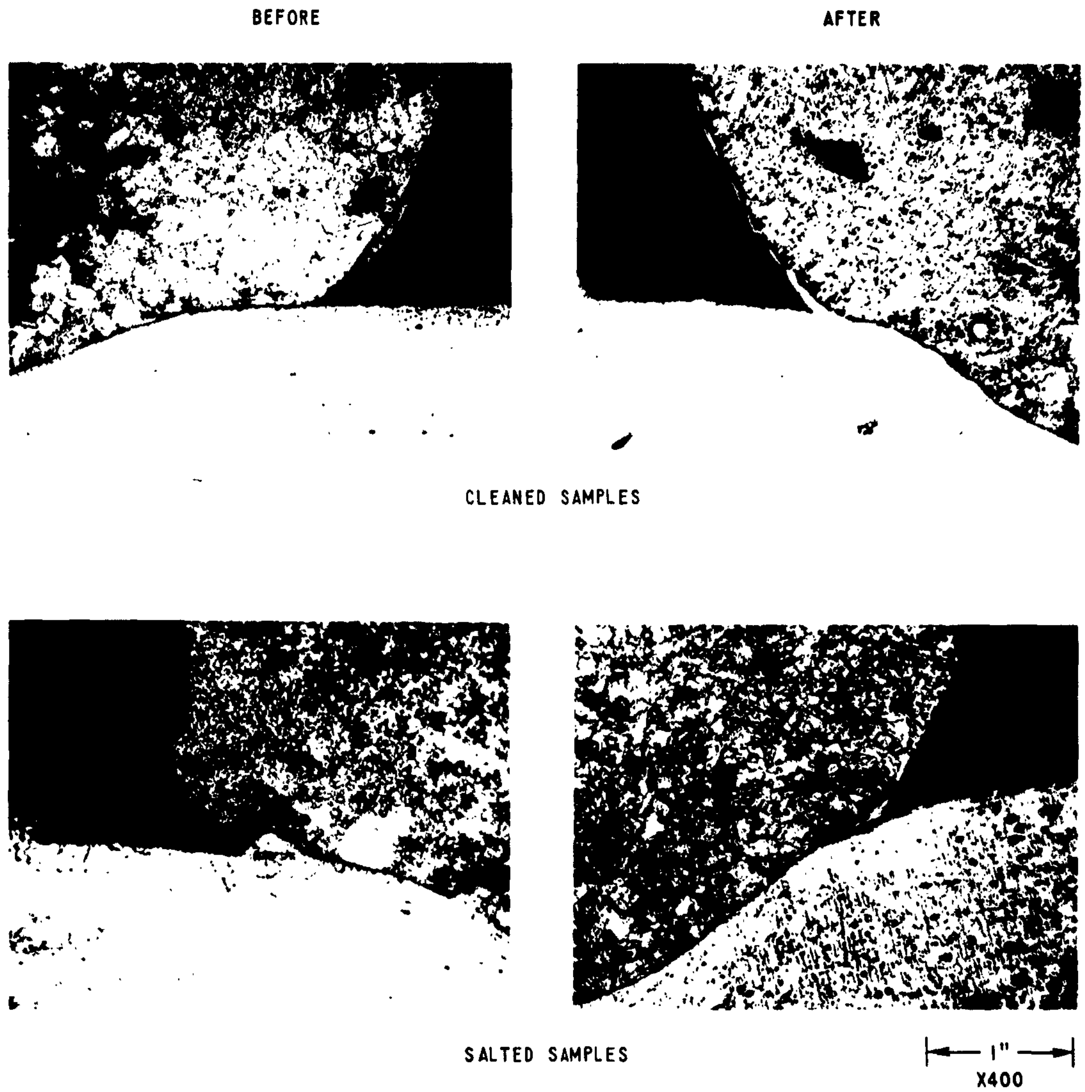
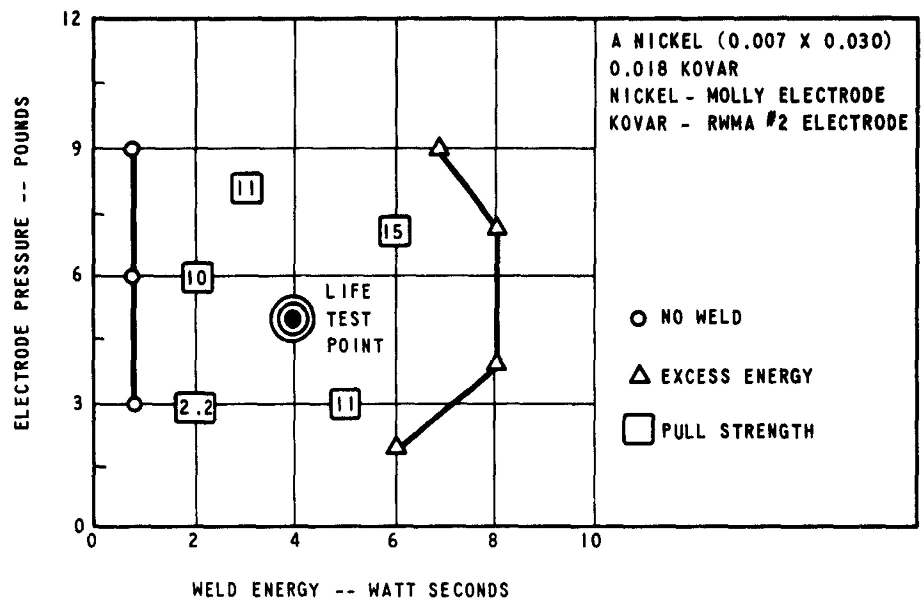


Figure 7

Test No. 1 -- Microphotographs of Tin Plated Copper to Nickel Welds Life Tested at 1650 hours at .3 amps and 4440 hours at 3 amps

TEST TWO



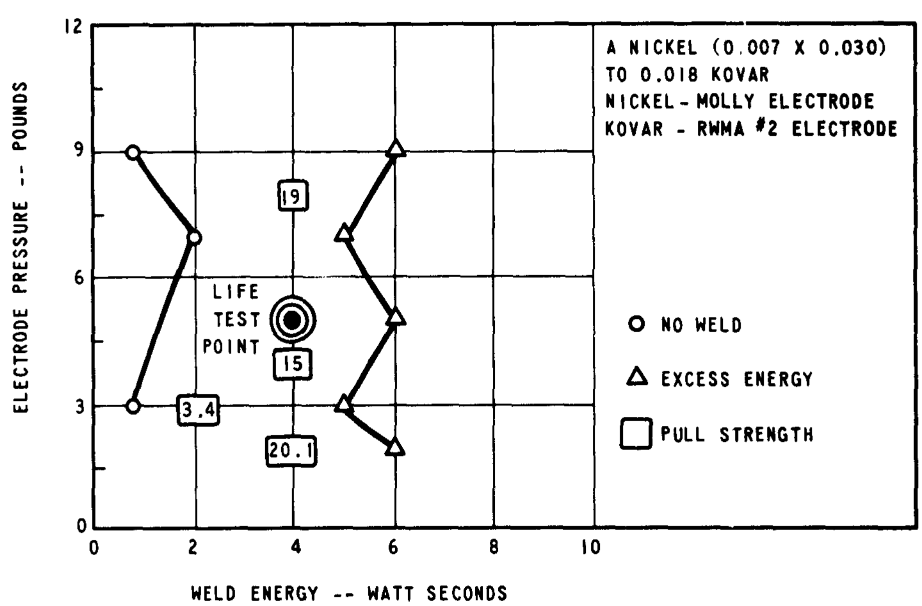


Figure 8

Test No. 2 -- Schmoo Diagram

Kovar to Nickel Welds

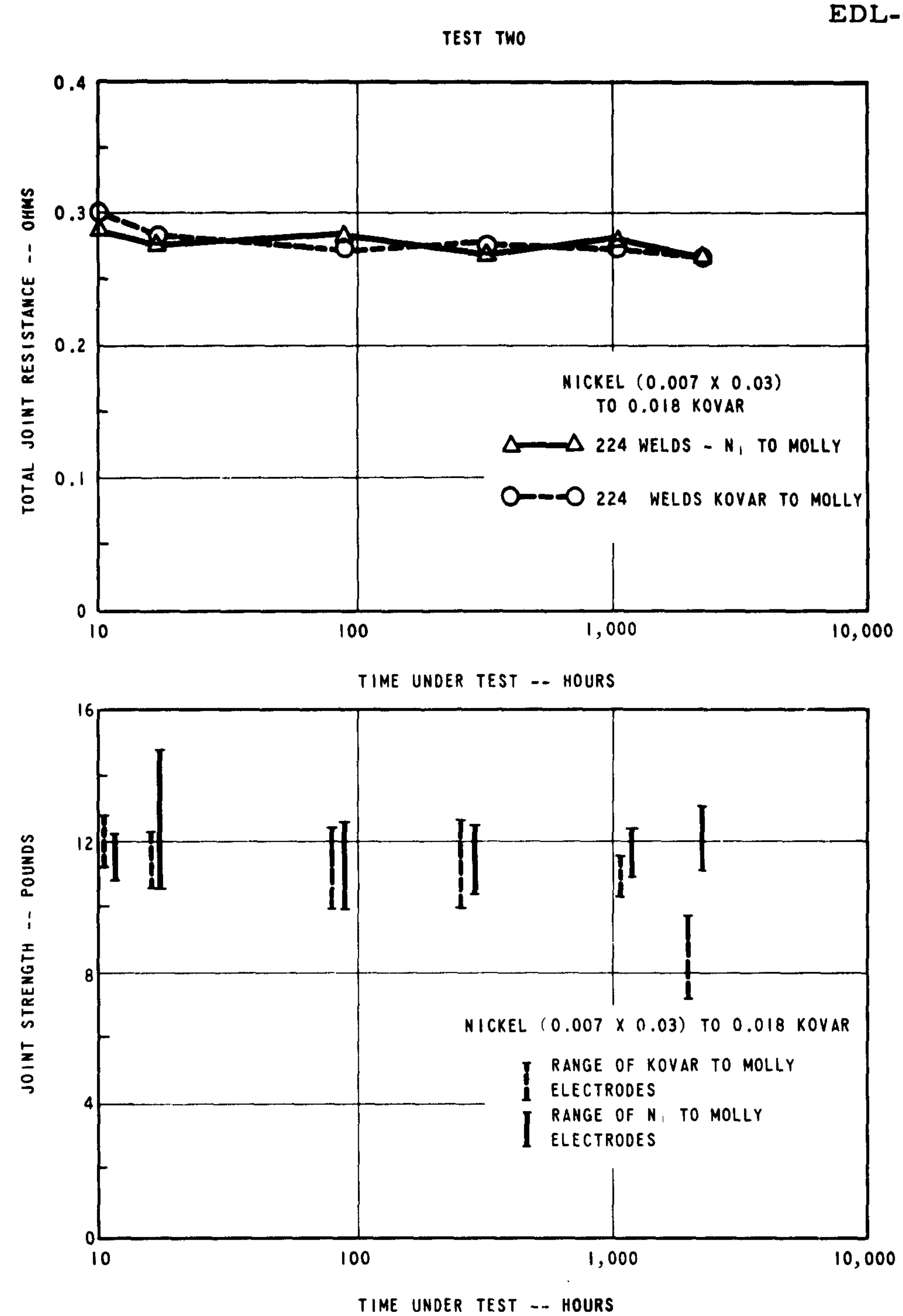


Figure 9

Test No. 2 -- Joint Resistivity and Joint Strength
of Kovar to Nickel Welds

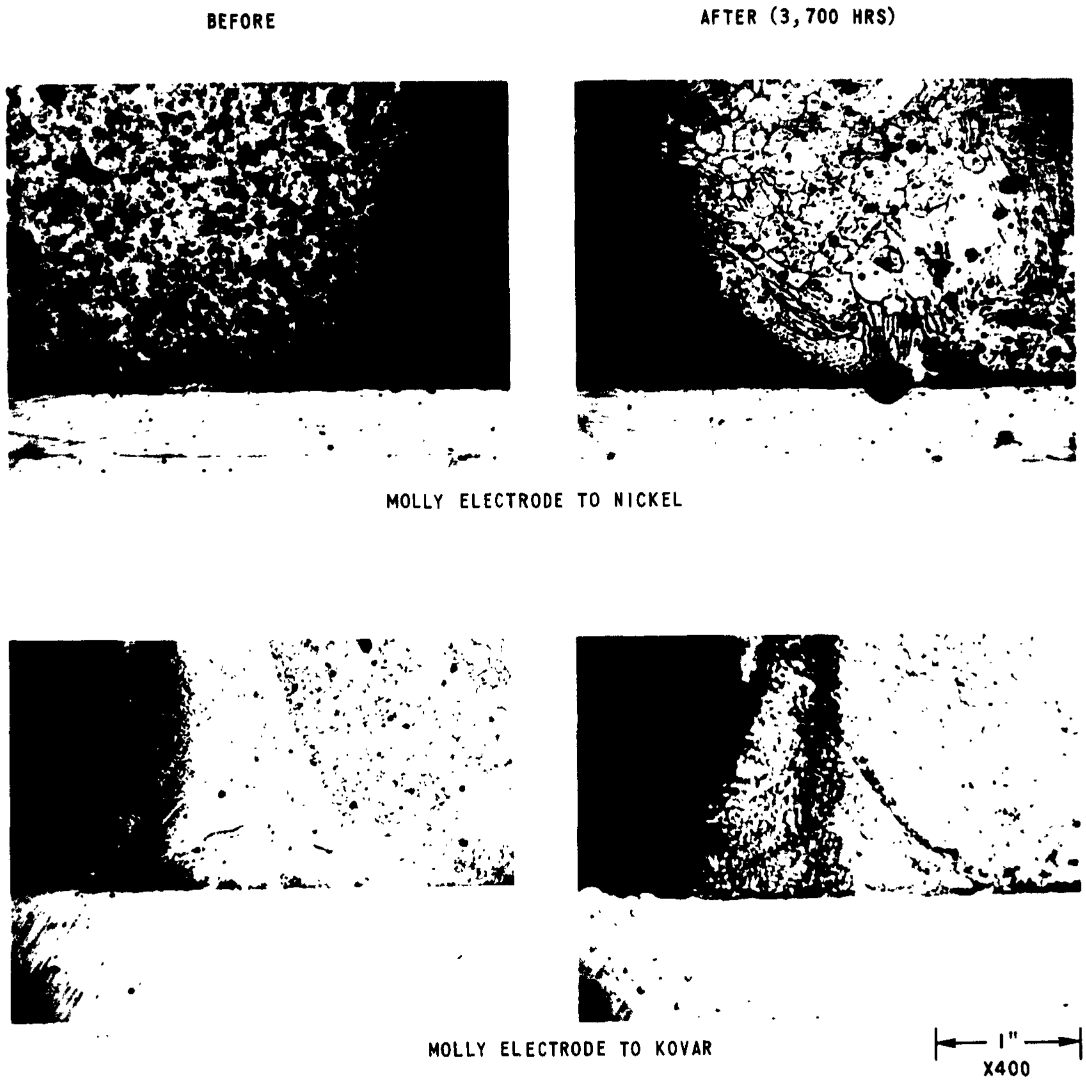


Figure 10

Test No. 2 -- Microphotographs of Kovar to Nickel Welds with REMA 2 and Molly Electrodes Life Tested at 3700 hours at 1 amp

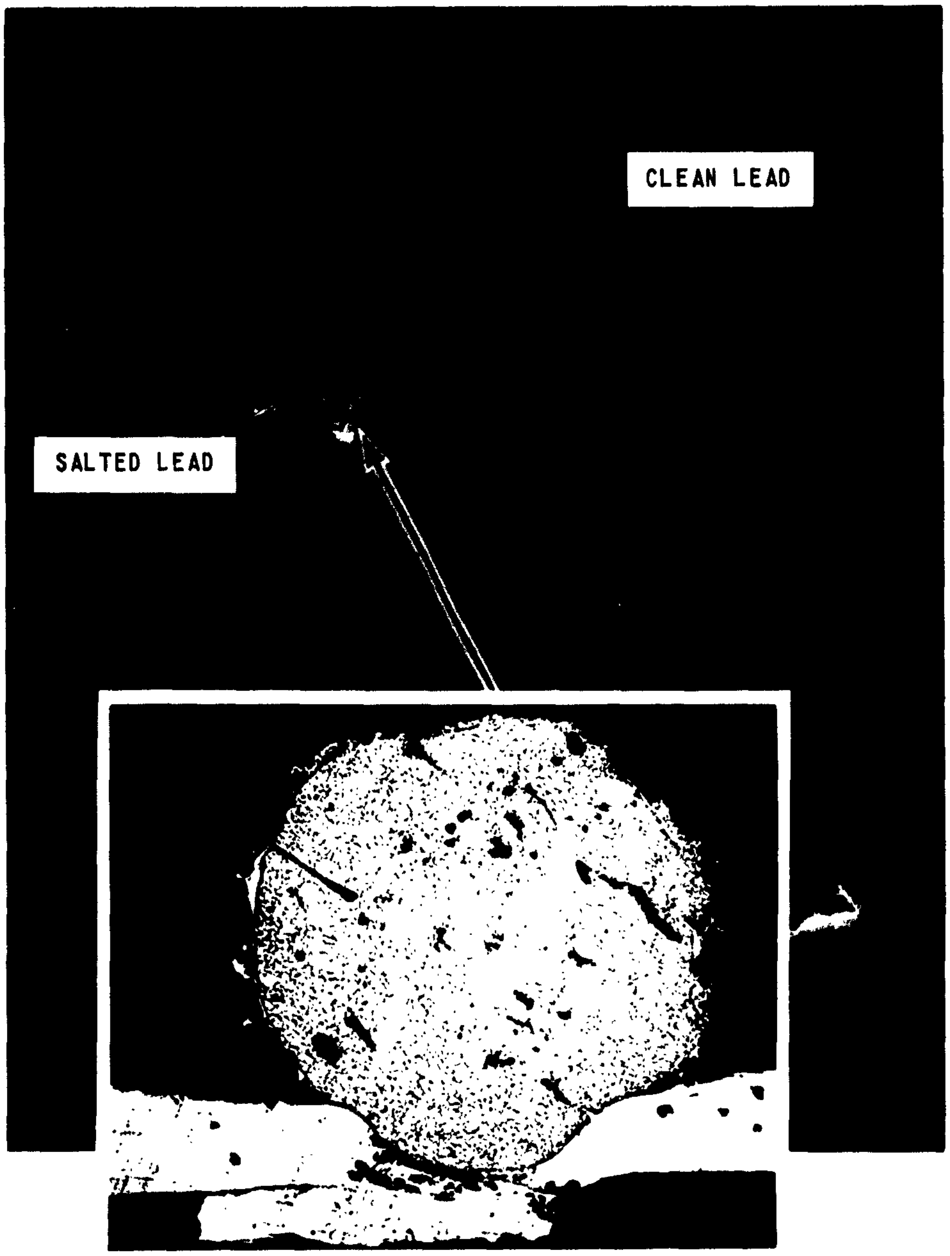


Figure 11

Test No. 4 -- Comparison Between Clean
and Salted 1/4 watt Resistor Leads After
3700 hours at 95% Relative Humidity and Test Current of 1 amp.

TESTS 3 AND 4

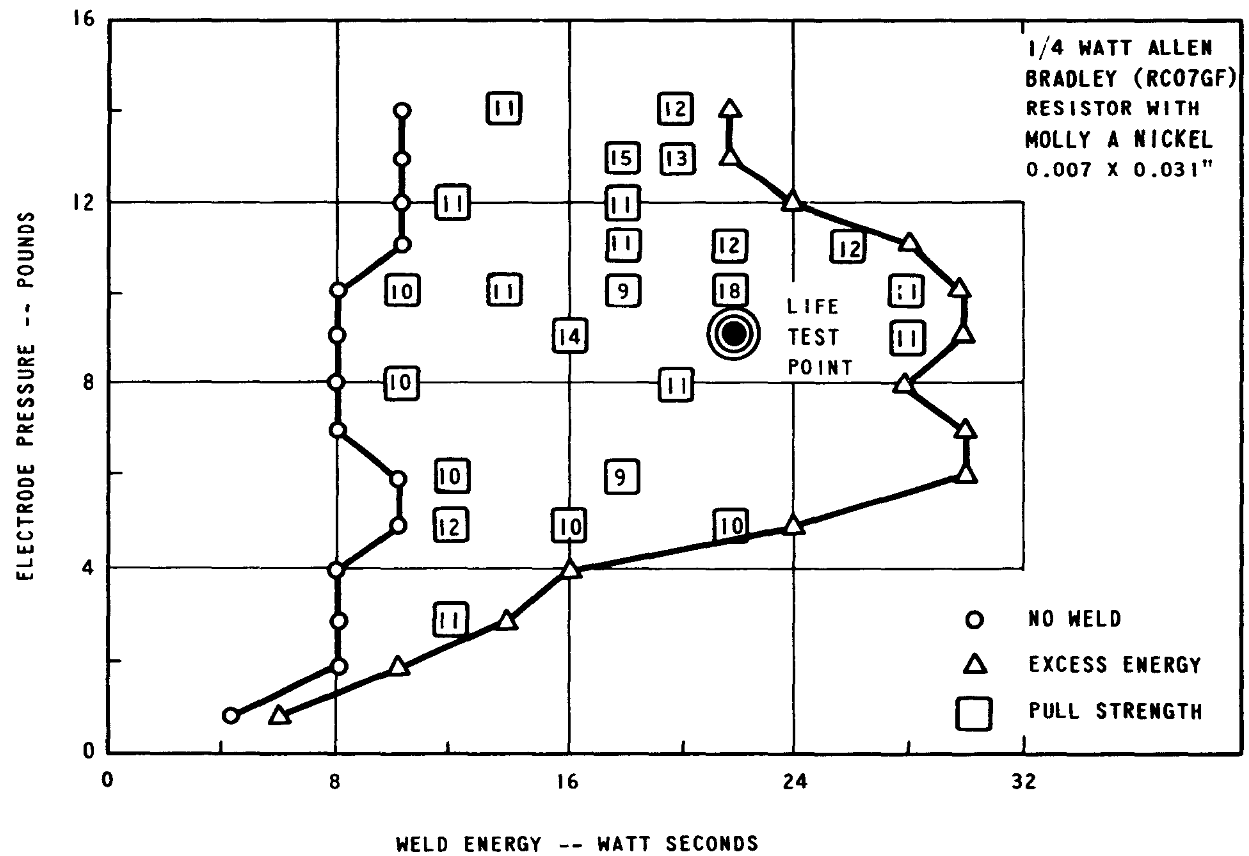


Figure 12

Tests 3 and 4 -- Schmoo Diagram 1/4 watt Resistor Leads to Nickel Welds

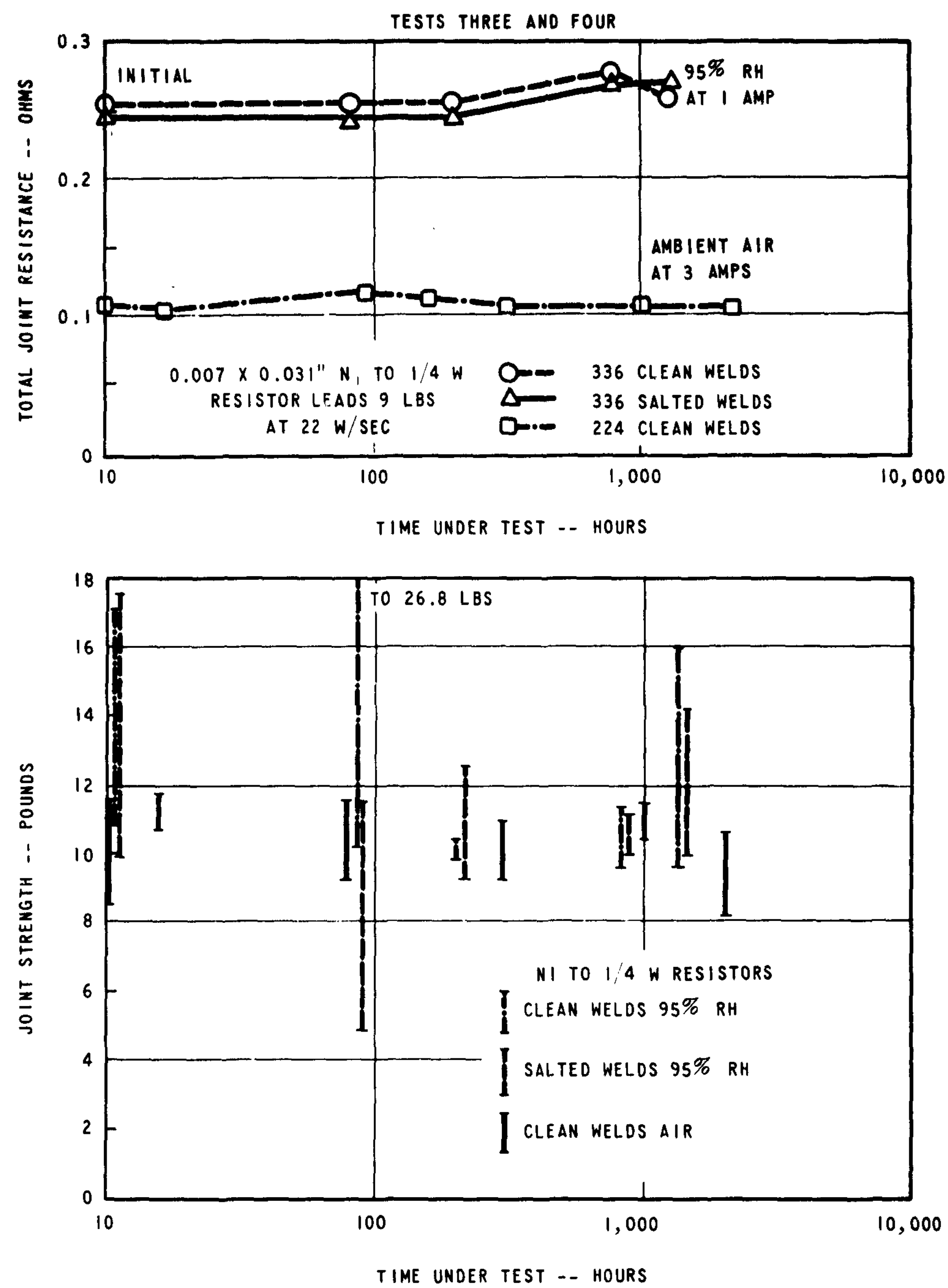


Figure 13

Tests 3 and 4 -- Joint Resistivity and Joint Strength of 1/4 watt Resistor to Nickel Welds

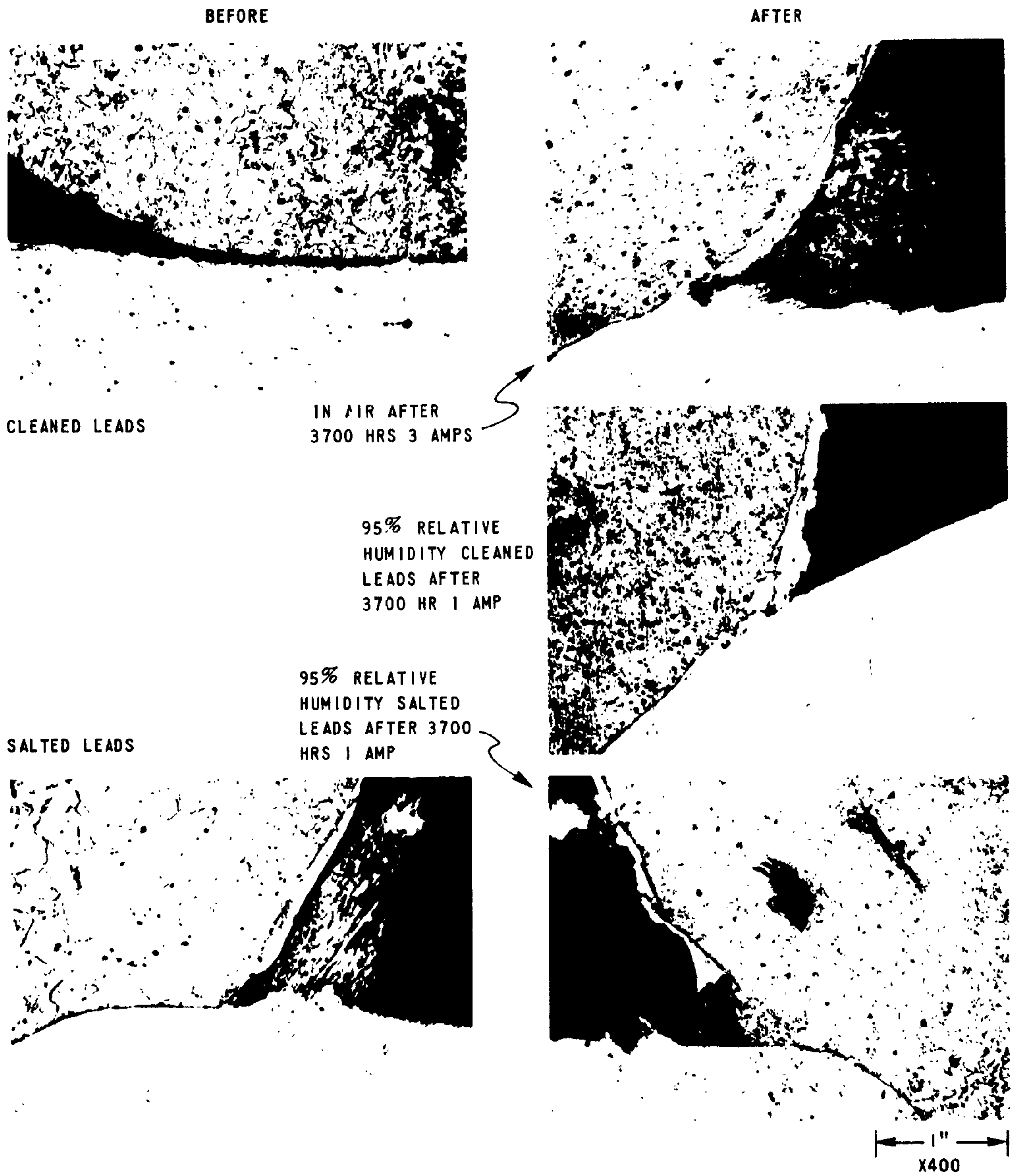


Figure 14

Tests 3 and 4 -- Microphotographs of 1/4 watt

Resistor to Nickel Welds

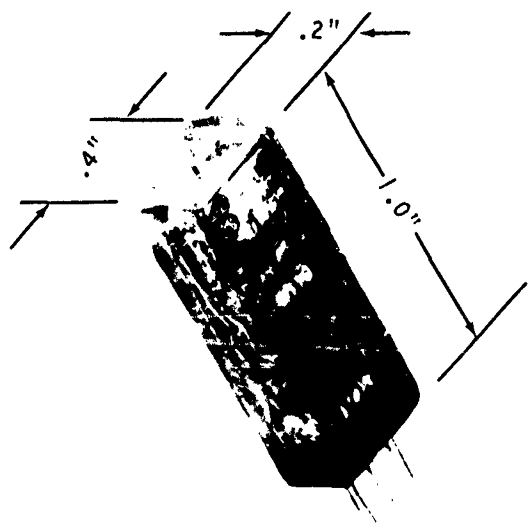


Figure 15

Example of Miniaturization (Binary Counter)

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Electronic Defense Labs., Mountain View, Calif.
RELIABILITY OF WELDED ELECTRONIC CONNECTIONS - Mark Hurowitz. Technical Memorandum EDL-M473, 23 May 1962 (Contract DA 36-039 SC-87499) UNCLASSIFIED Report.

In four life tests being run at EDL to determine the reliability of welded electronic connections, measurements for joint resistivity and joint strength are made on each of several sets of samples. Respectively, the tests involve nickel ribbon welded to #24 buss wire, nickel strap to Kovar transistor welds and nickel ribbon to 1/4 watt resistor leads (RC07GF). Some of these tests are being run in the open while others are being run under 95 relative humidity for both cleaned and salted samples. A dc current has been passed through the samples to accelerate joint failure. After a total of 6.9 x 10^6 weld hours of life test, no joint failures have been recorded. Moreover, no gross joint deterioration has occured.

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1. *Reliability
2. *Welded
3. *Electronic
4. *Connection
5. Resistivity
6. Strength
7. Nickel
8. Ribbon
9. Joint
10. Failure
11. Salt
12. Contamination
13. Humidity

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